Computational Modeling of Nondestructive Evaluation, Defect Detection, and Defect Identification for CFRP Composite Materials

Completed Technology Project (2015 - 2018)

Project Introduction

The objective of the proposed work is to improve NDE state-of-the-art for detection and identification of manufacturing and service-initiated defects in CFRP composite structures. The work will utilize computational models of the interaction of NDE probing energy fields with the composite structure and the imbedded defect, to study 1) the measured signal dependence on material and defect properties (forward problem), and ultimately, 2) the assessment of performance-critical defect properties from analysis of NDE signals (inverse problem). Generally speaking, the forward problem is mathematically well-posed, amenable to a well-established array of computational approaches, whereas the inverse problem is by-and-large ill-posed, and in need of novel conceptual development leading to robust meaningful solutions. Regarding the forward problem, computational models will be employed appropriate for simulation of NDE measurements in potentially large complicated geometry composite laminate structures. Work will primarily address ultrasound and thermography NDE modalities. A premise of the work is the availability of computational models capable of predicting measurement response for specified NDE measurement instrumentation systems, composite structures, and embedded defects. CNDE has in place computational models for a large relevant class of structural configurations, and is poised to further enhance current simulation capabilities as the proposed research requires, reflecting NASA€™s interests. This simulation capability provides the infrastructure for handling the forward measurement problem. Regarding the inverse problem (i.e. the determination of flaw characteristics through analysis of measured signals), work will seek to constrain the ill-posed data inversion through optimization of supplemental measures of defect properties. While measured data is usually insufficient to uniquely determine the defect properties (size, shape, and constituents), a large percentage of solutions compatible with the limited measured data are inconsistent with physical properties of actual defects (e.g. the defect must be contained solely within the structure). The proposed research will explore the effectiveness of various quantitative measures of defect properties in constraining the ill-posed inversion, and the possibility of formulating measures capable of discriminating between flaw types of particular interest (e.g. ply delamination versus distributed porosity) when applied to Bayesian estimation of defect properties using limited measured data. The effectiveness of the computational models will be benchmarked against experimentally measured signals in composite structures containing defects possessing known properties. The computational tools will facilitate the design of NDE inspections, so as to provide an effective balance of defect sensitivity and efficient large area coverage. Although explicit demonstration will be limited primarily to ultrasound and thermography, the concepts emerging from the proposed work will be applicable to a broad range of NDE modalities.

Anticipated Benefits

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Table of Contents

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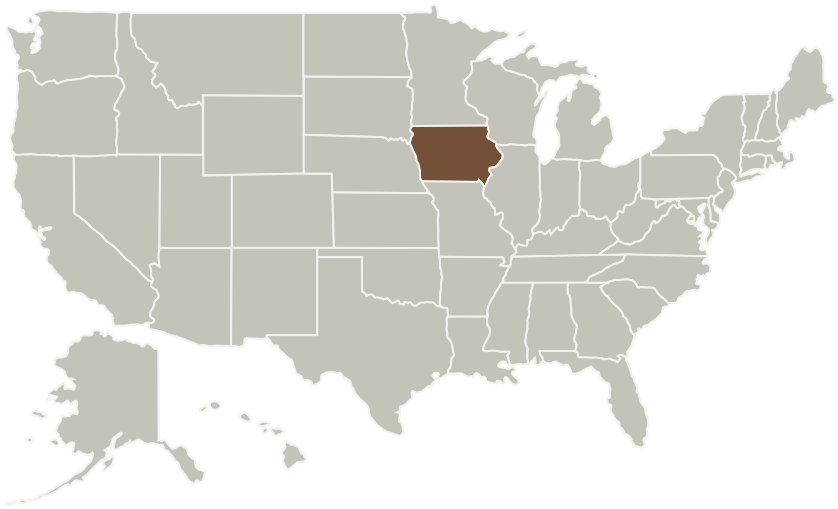
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Iowa State University	Lead Organization	Academia	Ames, Iowa

Primary U.S. Work Locations
Iowa

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Iowa State University

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

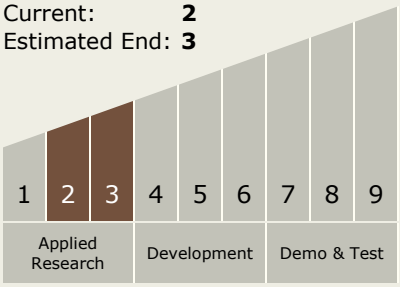
Hung D Nguyen

Principal Investigator:

Ronald Roberts

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



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Technology Areas

Primary:

- TX13 Ground, Test, and Surface Systems
  - TX13.2 Test and Qualification
    - TX13.2.3 Non-Destructive Inspection, Evaluation, and Root Cause Analysis

Target Destination

Foundational Knowledge